Overview of SMTF RF Systems

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Overview

- Scope of RF Systems
- RF & LLRF Collaboration
- Status
- LLRF Specifications for SMTF
- Long Term Goals
- Conclusions

Scope of RF Systems

- A0 - Gun and cavity
- Meson (Oct, 05) - CapCav2 with 300kW klystron
- Meson (06) - 325 MHz Proton Driver
- Injector Upgrade (06) - Gun, CapCav1, CapCav2, 3.9 GHz Accelerating and Deflecting Cavities
- IB1 Horizontal Test Stand -300kW
- Multi-cavity module support at New Muon Lab
- CW Program

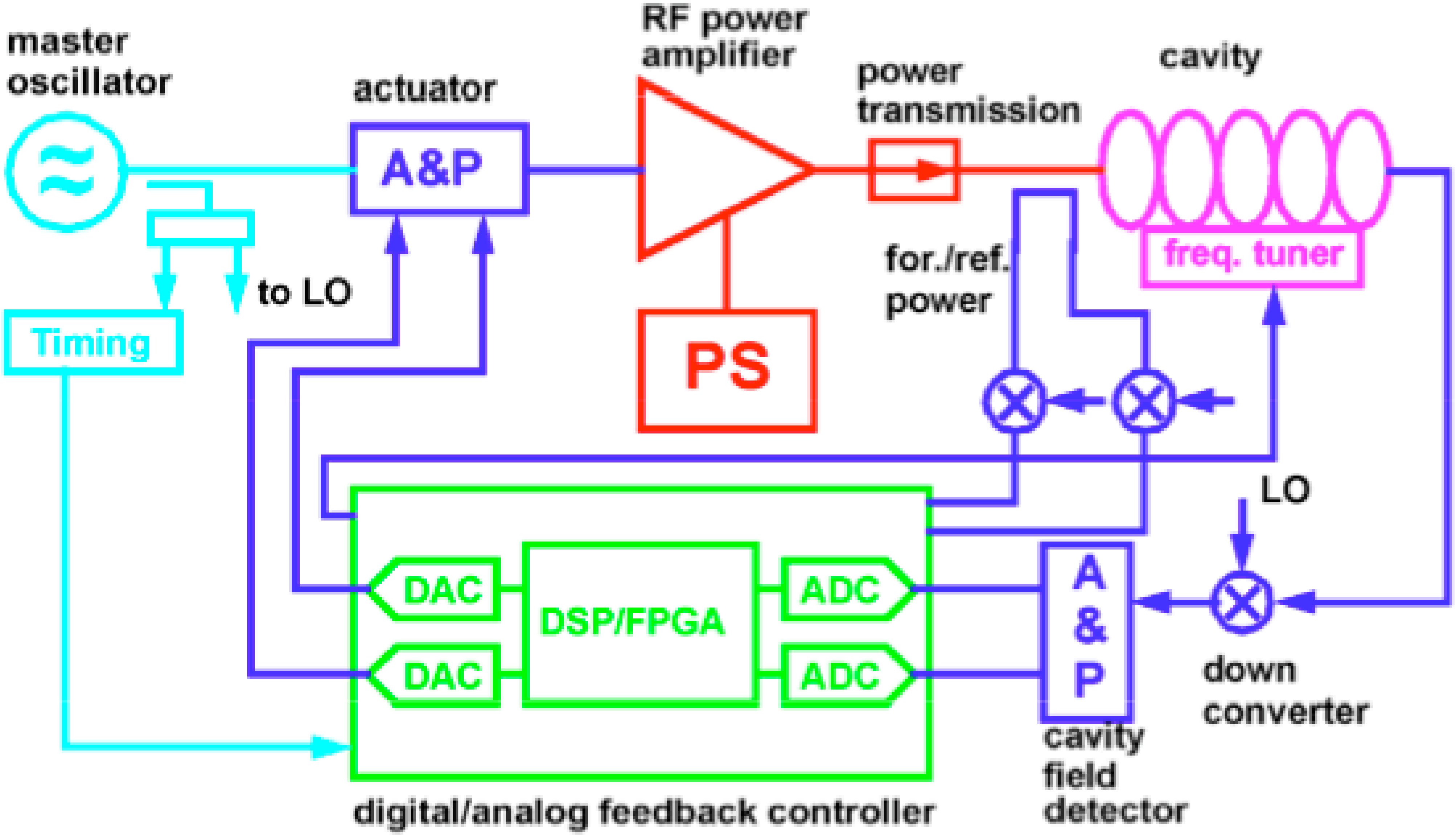
RF & LLRF Collaboration

- Fermilab Accelerator, Technical, and Computing Divisions
- DESY
- Penn State
- SNS and Jlab advisory capacity for now
- We want to expand this engineering collaboration!

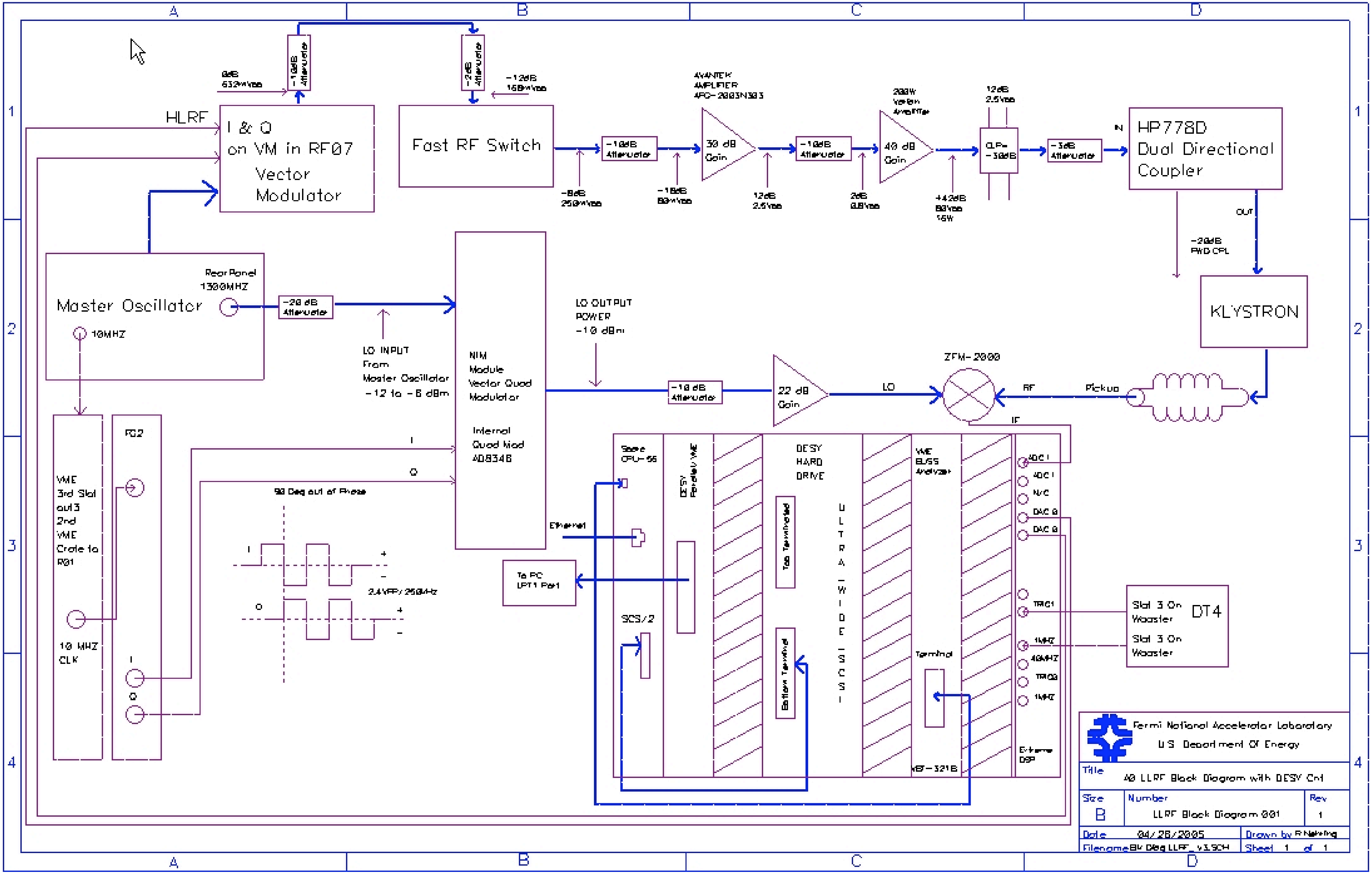
LLRF Progress to Date

- We have a DESY prototype FPGA LLRF controller that has been tested on the 9 cell cavity at A0. We are studying the FPGA firmware and the control interface.
- A stand alone LLRF system is being assembled for Meson October.
- A proven Timing system will be installed at Meson.
- EPICS and DOOCS control efforts are getting organized.
- A design for a Low Noise Master Oscillator is underway.
- Meetings are being held to bring more people into the effort.
- An RF and beam modeling and simulation group is meeting weekly for the Proton Driver. These efforts will spill over to the ILC.

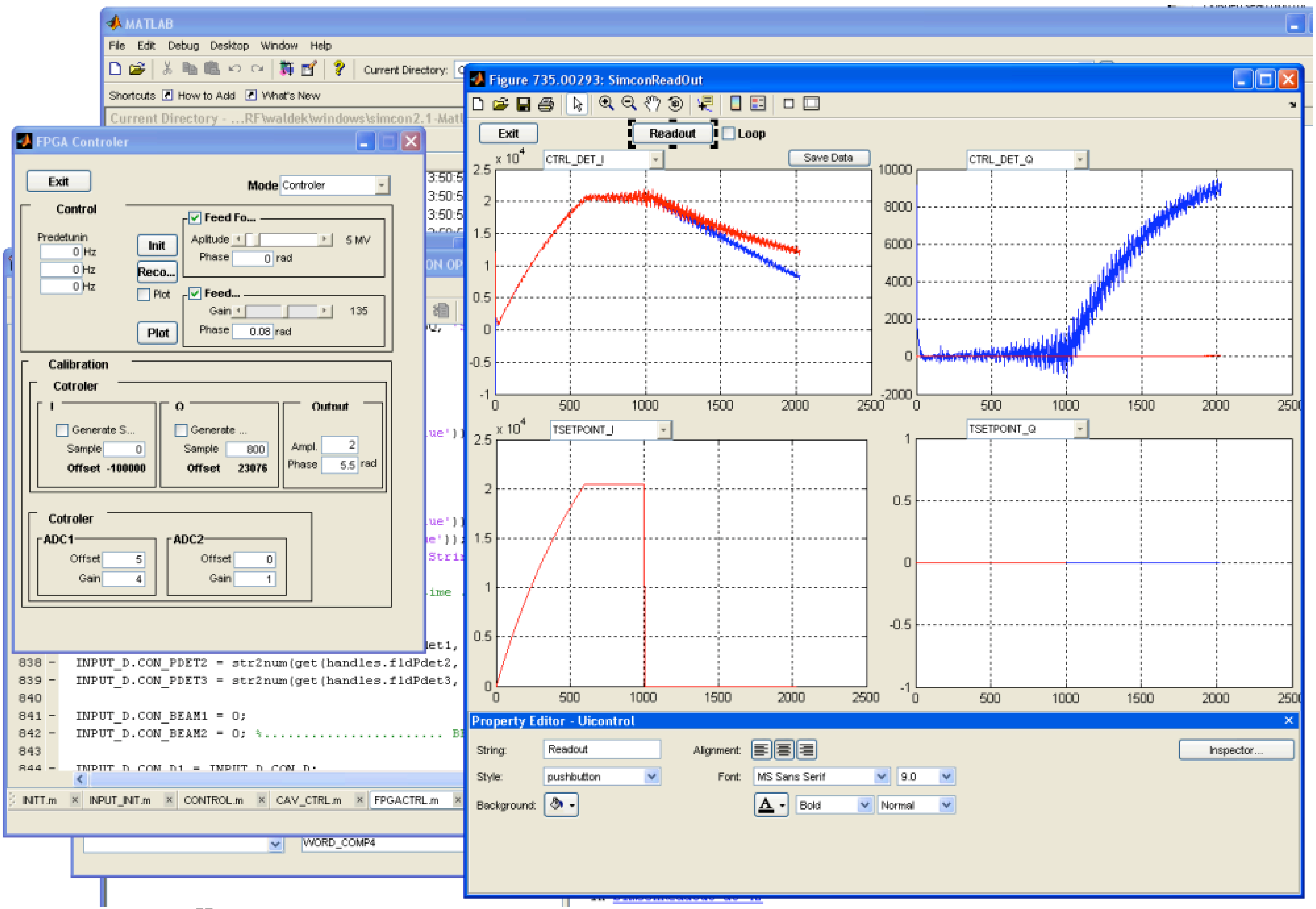
RF System Architecture



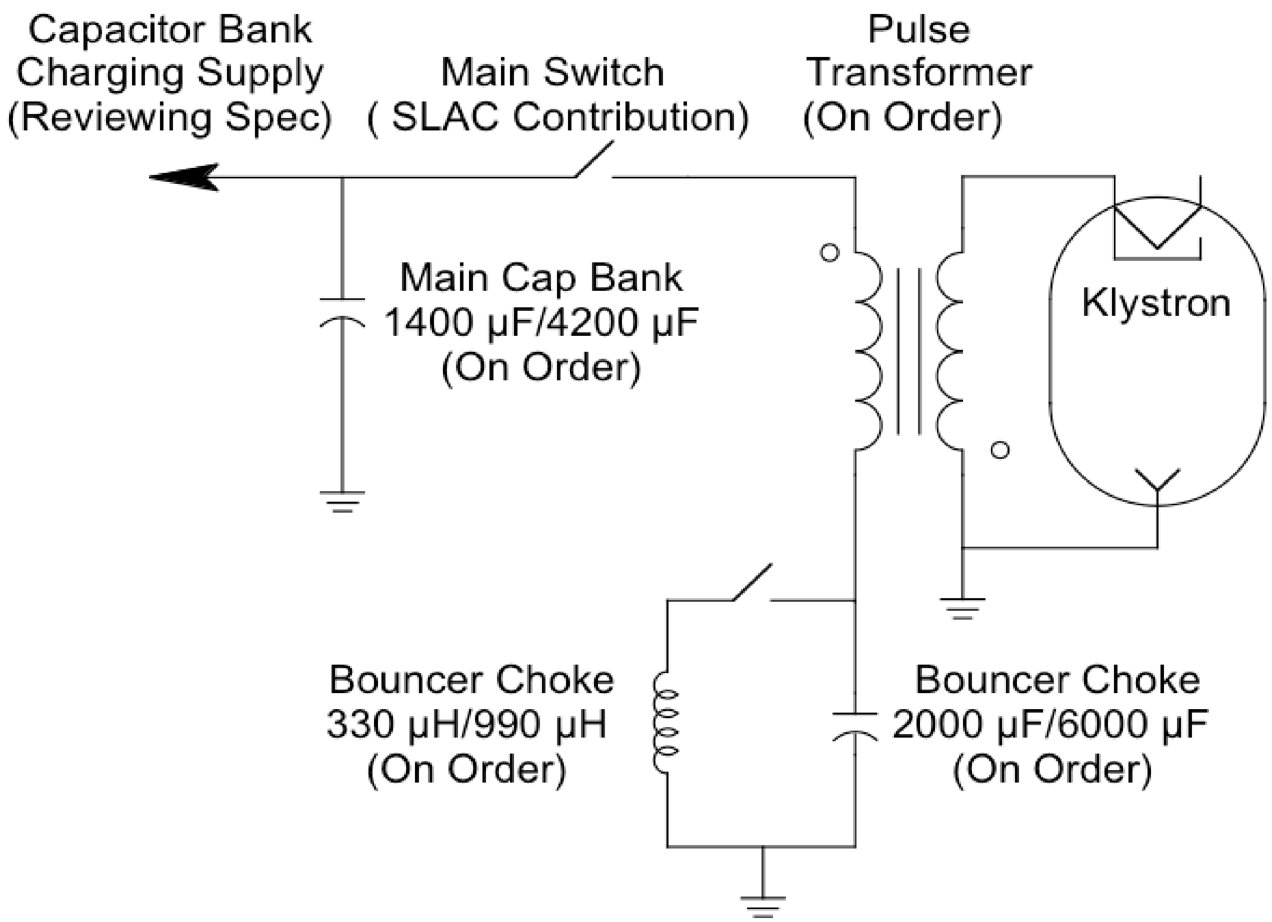
SIMCON 2.1 setup at A0 – March 2005



SIMCON 2.1 @A0 - Closed Loop – March 2005



Modulators



- Two modulators are being built
- One modulator end of this year, other early next year
- One with 4.2 ms flat top, other with 1.4 ms flattop
- Peak Output is 120 kV, 140 A
- Average Power is 310 kW

1.3 GHz 300 kW Klystron – Valvo Philips YK-1240 with solenoid & oil tank

300 kW 1.3 Ghz Klystron Station

- 300 Kwatt Klystron, solenoid, & oil tank are on hand
  - Socket is being rebuild for filament & cathode connection
  - Drawings completed. Parts ready to be fabricated in machine shop
  - Good klystron tube ready to install

- Charging supply & capacitor bank are in process of being assembled
  - Major parts on hand expect for capacitors
  - Capacitor manufacturer waiting for insulators

- Modulator
  - Assembly of modulator has started
  - HV isolations transformers are ready to install into oil tanks & test
  - Working on HV deck layout & procuring chassis parts

- Controls & Interlocks
  - Lab G modules have been retrieved
  - Modifications ready to start along with additional new modules for rf signal processing

- Waveguide, isolator, directional couplers, bellows, & misc parts
  - In process of making procurements

KLYSTRON INTERLOCKS

(4th Generation)

Monitor

- Forward and Reflected Power at the klystron output directional coupler.
- Forward and Reflected Power at the load and circulator (if used).
- Inhibit Klystron LLRF drive when 3 consecutive reflected power trips are detected.
- Waveguide Pressure.
- RF Leakage Level.
- Klystron Window and waveguide sparks.
- Load and Circulator window sparks.

Permits

- Enable LLRF when all klystron interlocks are clear.
- Enable Modulator to pulse when all klystron interlocks are clear.

System Implementation

- VME Based system running under EPICS.
- Consist of three 4 Channel VME boards and a slot 0 crate controller.
- Any trip inhibit LLRF permit < 1 usec.

Code development for SRF linacs at Fnal:

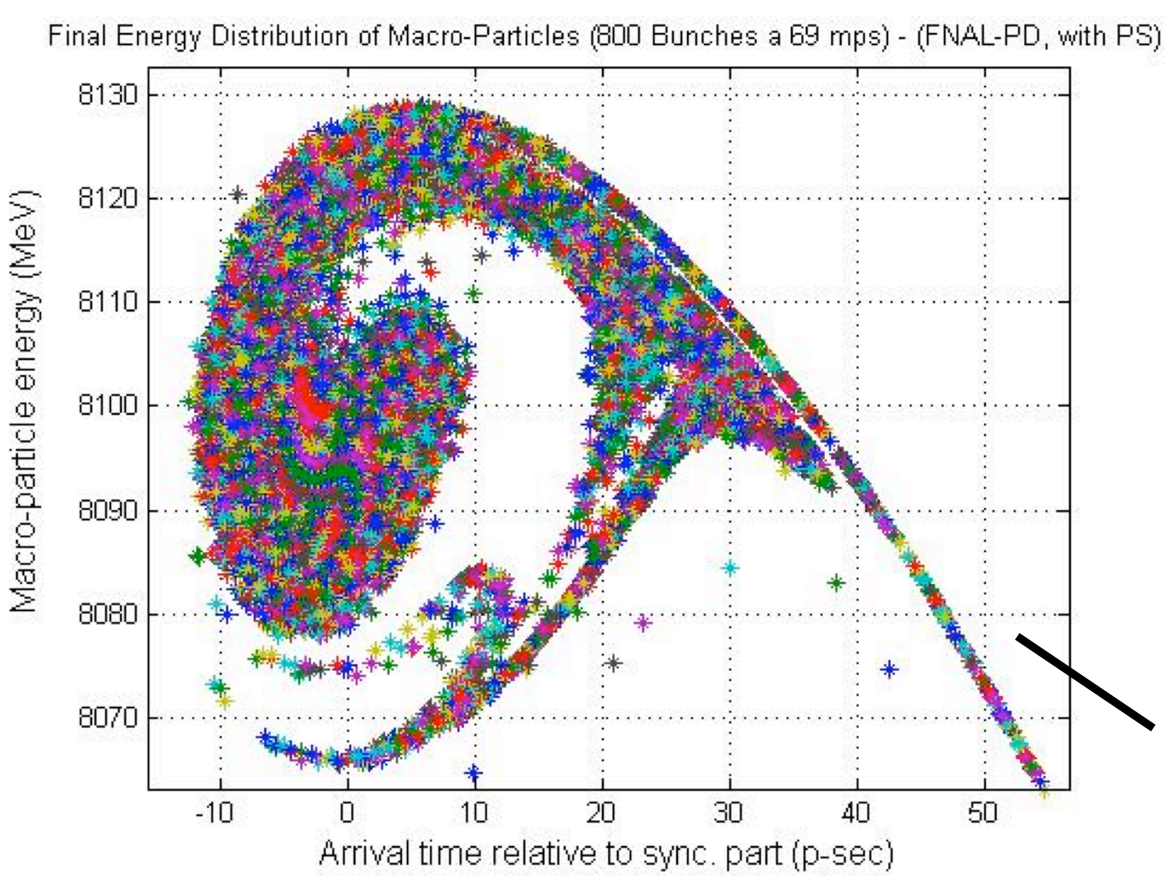
M. Huening's S.C.R.E.A.M

•Developed for TTF

• incorporates "realistic" implementation of vector-sum control and cavity detuning due to Lorentz-forces and microphonics

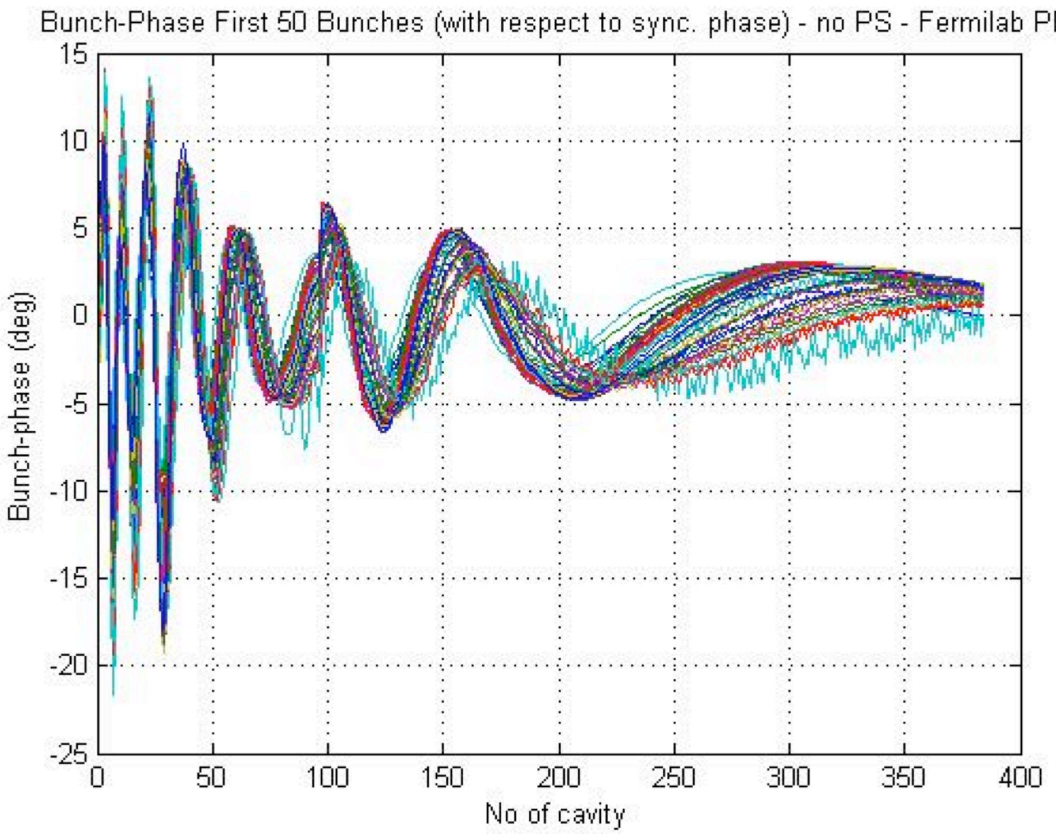
•Simulates effect of cavity detuning and respective RF controls measures on longitudinal beam phase-space

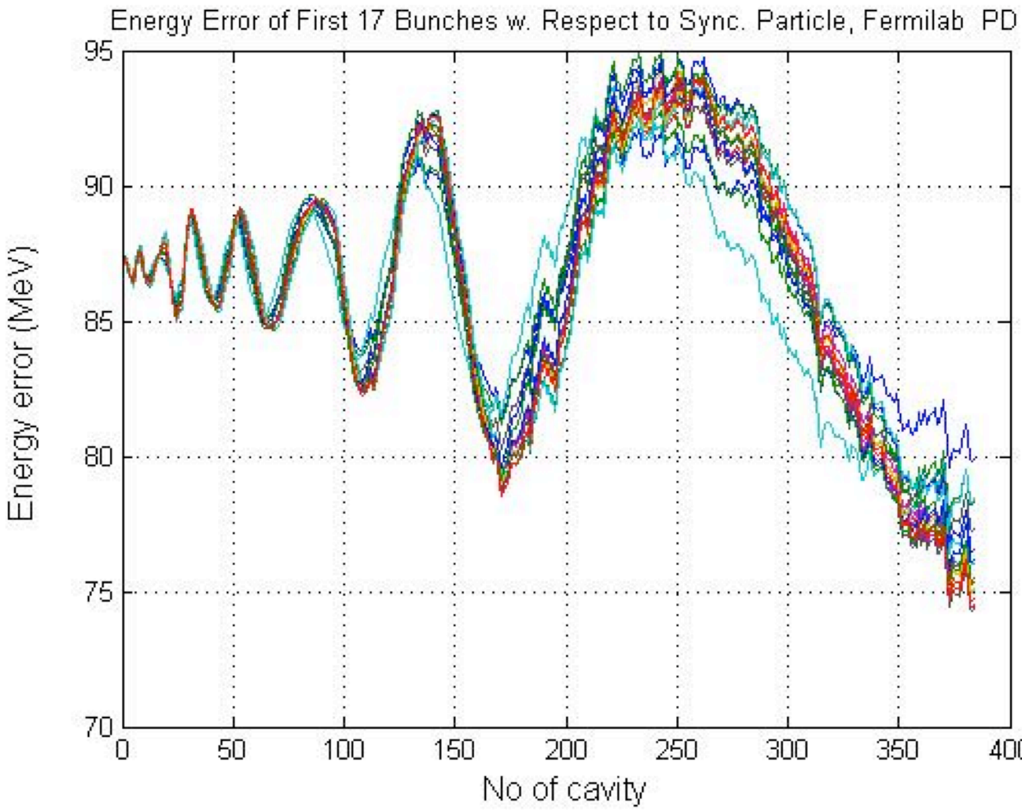
•Special adaptation to Fnal PD: includes fast ferrite vector-modulator



Left: Final longitudinal phase-space distribution of all macro-particles accelerated in the PD during a 1.3 msec pulse.

Below: Example of S.C.R.E.A.M simulations of average bunch phase and energy along linac during different times along the PD linac as an illustration for the need of accurate beam phase control needed in the low beta end of linac to control beam energy fluctuations at output.





Sources of Perturbations

- o Beam loading
  - Beam current fluctuations
  - Pulsed beam transients
  - Multipacting and field emission
  - Excitation of HOMs
  - Excitation of other passband modes
  - Wake fields
- o Cavity drive signal
  - HV- Pulse flatness
  - HV PS ripple
  - Phase noise from master oscillator
  - Timing signal jitter
  - Mismatch in power distribution
- o Cavity dynamics
  - cavity filling
  - settling time of field
- o Cavity resonance frequency change
  - thermal effects (power dependent)
  - Microphonics
  - Lorentz force detuning
- o Other
  - Response of feedback system
  - Interlock trips
  - Thermal drifts (electronics, power amplifiers, cables, power transmission system)

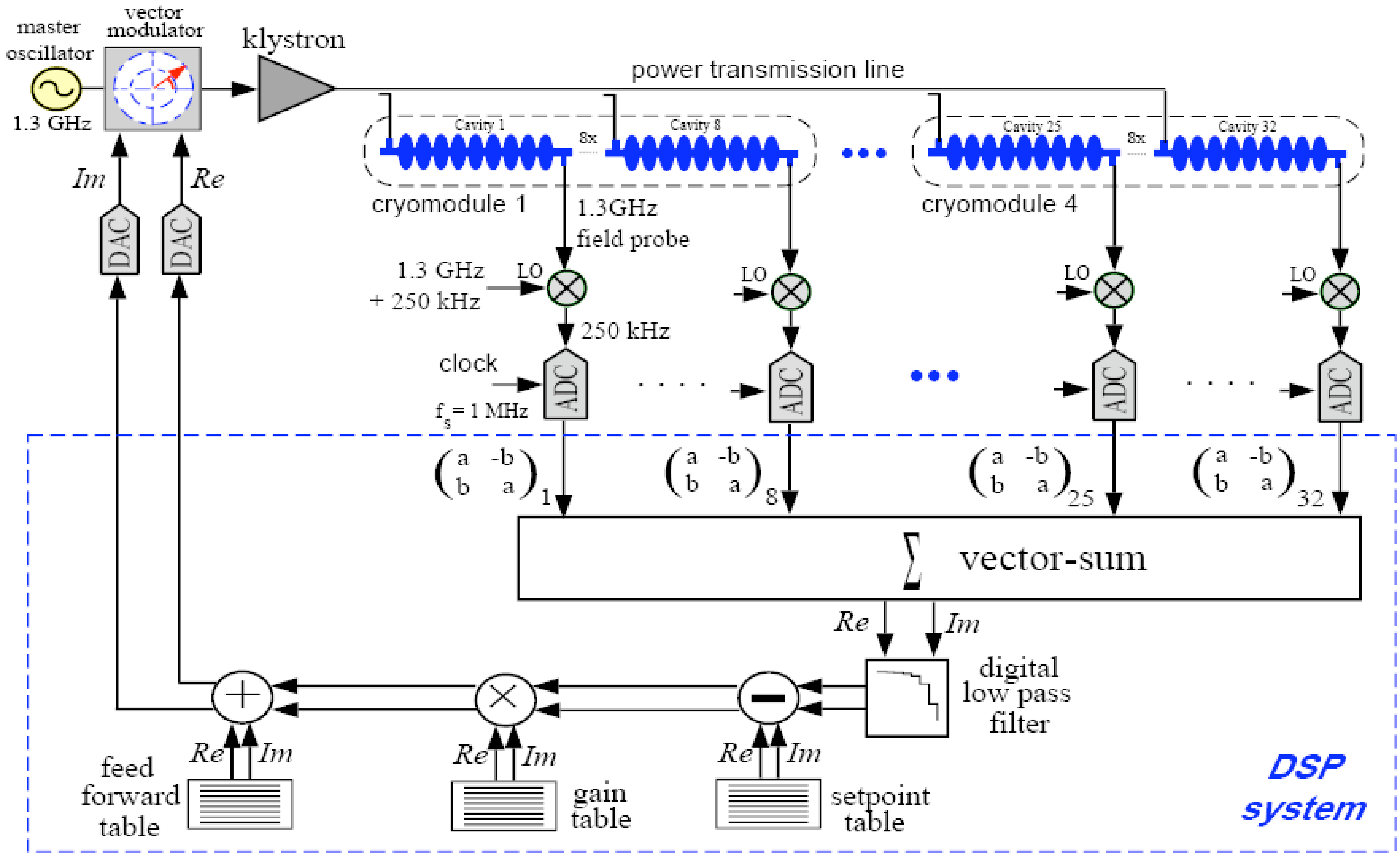
LLRF Specifications for SMTF
(Most Stringent Compilation)

- 1 to 4.5 ms pulse length or CW operation
- Variable rep rates up to 10 Hz
- 0.5 deg, 0.5% pulsed, 0.01 deg, 0.01% CW
- 0.1 deg, 0.03% correlated
- 325 & 1300 MHz warm/cold, and 3900 MHz cold only
- Multiple cavity per klystron operation
- Piezo tuner control
- Ferrite Vector Modulator control

RF Parameters

Parameter/ System	ILC	Proton Driver	CW
Uncorrelated Amplitude	0.5%, 0.5 deg	0.2%, 0.3 deg	0.01 %, 0.01 deg
Correlated	0.03%, 0.1 deg	0.03%, 0.1 deg	0.01 %, 0.01 deg
Bunch to Bunch Energy	0.05%		
Stored Energy W	144J/m	80.5J/m	
Gradient	35MV/m	26 MV/m	
Beam Current	9.5mA	8.3mA	
Uncorrelated / Klystron	0.5%		
Klystrons/Linac	286	12	
Cavities/Klystron	24 or 36	36 to 48	
Loaded Q	2.6E6	1.5E6	3E10 unloaded Q

Digital Control at the TTF



LLRF R&D at SMTF

- Short run - TTF clone
  - Support operations at A0 and Meson
  - Develop collaboration
  - Explore Remote Operation
- Next few years - XFEL and ILC goals
  - Master Oscillator and other hardware
  - Control algorithms and state control software
  - Optimize klystron, modulator and control specifications and designs for performance and cost

Conclusions

- High Power RF, Modulators and Interlocks are on a clear path.
- LLRF is moving forward on a collaborative effort with DESY and other institutions
- Simulation for Proton Driver are underway - could apply to ILC
- R&D efforts at SMTF are to make the RF Systems meet specifications, improve automation and to lower costs for the ILC